

example, pyrophosphates, phosphonoacetic acid, ethylenediphosphonic acid, 1-hydroxyethylidene-1,1-diphosphonic acid, and mixtures thereof. Preferred phosphorous-containing compounds also include, for example,  $M_n^{+1}H_{3-n}PO_4$  and  $M_m^{+1}H_{4-m}P_2O_7$ , wherein  $M^{+1}$  is a cationic species (e.g., Na, K, Cs, Rb,  $NH_4^+$ ), n = 0-3, and m = 0-4. Moreover, a preferred phosphorous-containing compound is R-O-PO<sub>3</sub>, wherein R is an organic moiety selected from the group consisting of alkyl, aryl, cyclic, and aromatic groups having from 1-18 carbon atoms.

*Replace the paragraph beginning at page 5, line 30, with:*

Preferably, at least one polishing additive comprises the structure XY-NCR<sup>1</sup>R<sup>2</sup>CR<sup>3</sup>R<sup>4</sup>N-X'Y', wherein X, Y, X', Y', R<sup>1</sup>, R<sup>2</sup>, R<sup>3</sup>, and R<sup>4</sup> are selected from the group consisting of hydrogen (H) atoms, heteroatom-containing functional groups, alkyl groups, heteroatom-containing alkyl groups, cyclic groups, heteroatom-containing cyclic groups, aromatic groups, heteroatom-containing aromatic groups, and combinations thereof. More preferably, at least one polishing additive comprises the structure XY-NCR<sup>1</sup>R<sup>2</sup>CR<sup>3</sup>R<sup>4</sup>N-X'Y', wherein X and X' are H atoms, and wherein Y, Y', R<sup>1</sup>, R<sup>2</sup>, R<sup>3</sup>, and R<sup>4</sup> are selected from the group consisting of hydrogen (H) atoms, heteroatom-containing functional groups, alkyl groups, heteroatom-containing alkyl groups, cyclic groups, heteroatom-containing cyclic groups, aromatic groups, heteroatom-containing aromatic groups, and combinations thereof. Even more preferably, at least one polishing additive comprises the structure XY-NCR<sup>1</sup>R<sup>2</sup>CR<sup>3</sup>R<sup>4</sup>N-X'Y', wherein X, Y, X', and Y' are H atoms, and wherein R<sup>1</sup>, R<sup>2</sup>, R<sup>3</sup>, and R<sup>4</sup> are selected from the group consisting of hydrogen (H) atoms, heteroatom-containing functional groups, alkyl groups, heteroatom-containing alkyl groups, cyclic groups, heteroatom-containing cyclic groups, aromatic groups, heteroatom-containing aromatic groups, and combinations thereof. In this regard, nitrogen-containing compounds that consist of primary amine groups are preferred over nitrogen-containing compounds that comprise secondary amine groups and/or tertiary amine groups, alone or in combination with primary amine groups. Moreover, it is suitable for at least one polishing additive to comprise the structure as described above, wherein the structure is in the form of a polymer comprising about four or more (e.g., about 10 or more, about 15 or more, about 20 or more, about 30 or more, about 40 or more, or even about 50 or more) dissimilar, similar, or even identical adjoined structures. Most preferably, the nitrogen-containing compound is selected from the group consisting of polyethylenimine, 1,3-diamino-2-propanol, iminodiacetic acid, 2-amino-butanol, ethylenediamine, aminoethylethanamine, 2,2'-aminoethoxyethanol, and mixtures thereof.

*Replace the paragraph beginning at page 7, line 10, with:*

Suitable polishing additives also include one or more compounds selected from the group consisting of (i) compounds that are both phosphorous-containing compounds and nitrogen-containing compounds, (ii) compounds that are both phosphorous-containing compounds and sulfur-containing compounds, (iii) compounds that are both nitrogen-containing compounds and sulfur-containing compounds, and (iv) compounds that are phosphorous-containing compounds, nitrogen containing compounds, and sulfur-containing compounds. Preferred polishing additives include, for example, compounds selected from the group consisting of 2-aminoethylphosphonic acid, amino(trimethylenephosphonic acid), diethylenetriaminepenta(methylenephosphonic acid), hexamethylenediaminetetra(methylenephosphonic acid), and mixtures thereof. Moreover, preferred polishing additives include, for example, phosphonic compounds containing primary, secondary and/or tertiary amines, such as, for example, N-(phosphonomethyl)iminodiacetic acid, 2-aminoethyl dihydrogen phosphate, 2-aminoethylphosphonic acid, 2-aminoethylphosphonic acid, aminotri(methylenephosphonic acid) (i.e., Dequest® 2000 product), 1-hydroxyethylidene-1,1-diphosphonic acid (i.e., Dequest® 2010 product), and diethylenetriaminepenta(methylenephosphonic acid) (i.e., Dequest® 2060 product).

*Replace the paragraph beginning at page 8, line 9, with:*

The stopping compound can be any suitable cationically charged nitrogen-containing compound selected from the group of compounds comprising amines, imines, amides, imides, polymers thereof, and mixtures thereof. The term "cationically charged" as used herein means that a portion (e.g., about 5% or more, about 10% or more, about 15% or more, or about 20% or more) of the stopping compound in the liquid portion of the system is in cationic form at the operating pH of the system of the present invention. Preferably, the stopping compound has a pKa value that is 1 or more units greater than the operating pH of the liquid portion of the system. For example, in a system with a pH of 6.5, preferred stopping compounds would have a pKa value of about 7.5 or more. Preferred stopping compounds also are oppositely charged from the surface charge of the second layer of the substrate layer. Suitable stopping compounds include, for example, compounds comprising primary amines, secondary amines, tertiary amines, quaternary amines (i.e., quaternary ammonium salts), etheramines, oligomeric amines, oligomeric imines, oligomeric amides, oligomeric imides, polymeric amines, polymeric imines, polymeric amides, polymeric imides, or mixtures thereof. Moreover, suitable stopping compounds include, for example, amino acids, amino alcohols, amino ether alcohols, or mixtures thereof. Preferred stopping compounds also include, for example,

Polyetheramines, polyethylenimines, N<sub>4</sub>-amino(N,N'-bis-[3-aminopropyl]ethylenediamine), 4,7,10-trioxatridecane-1,13-diamine, 3,3-dimethyl-4,4-diaminodicyclohexylmethane, 2-phenylethylamine, N,N-dimethylpropyleneetriamine, 3-[2-methoxyethoxy]propylamine, dimethylaminopropylamine, 1,4-bis(3-aminopropyl)piperazine, and mixtures thereof. In addition, preferred stopping compounds include, for example, isophoronediamine, hexamethylenediamine, cyclohexyl-1,3-propanediamine, thiomicamine, (aminopropyl)-1,3-propanediamine, tetraethylenepentamine, tetramethylbutanediamine, propylamine, diaminopropanol, aminobutanol, (2-aminoethoxy)ethanol, or mixtures thereof.

*Replace the paragraph beginning at page 9, line 5, with:*

The system of the present invention can comprise any suitable combination of at least one polishing additive and at least one stopping compound. For example, the system can comprise polyethylenimine and at least one polishing additive selected from the group consisting of a carboxylic acid (preferably, a di-, tri-, or poly-carboxylic acid), a phosphate (preferably, a pyrophosphate, a tri-phosphate, or a condensed phosphate), an acid thereof, and a phosphonic acid (preferably, a di-, tri-, or poly-phosphonic acid). The system also can comprise at least one polishing additive selected from the group consisting of a carboxylic acid (preferably, a di-, tri-, or poly-carboxylic acid), a phosphate (preferably, a pyrophosphate, a tri-phosphate, or a condensed phosphate), an acid thereof, and a phosphonic acid (preferably, a di-, tri-, or poly-phosphonic acid) and at least one stopping compound comprising two or more, three or more, four or more, five or more, or even six or more nitrogen atoms (e.g., at least one stopping compound comprising two or more amine groups, at least one stopping compound comprising two or more primary amine groups, at least one stopping compound comprising two or more amino groups and 4 or more carbon atoms, or at least one stopping compound comprising two or more primary amine groups containing 3 or more carbon atoms). Moreover, the system can comprise at least one polishing additive selected from the group consisting of a carboxylic acid (preferably, a di-, tri-, or poly-carboxylic acid), a phosphate (preferably, a pyrophosphate, a tri-phosphate, or a condensed phosphate), an acid thereof, and a phosphonic acid (preferably, a di-, tri-, or poly-phosphonic acid) and a quaternary ammonium salt comprising the structure NR<sup>1</sup>R<sup>2</sup>R<sup>3</sup>R<sup>4</sup>, wherein R<sup>1</sup>, and R<sup>2</sup> are methyl groups and R<sup>3</sup> and R<sup>4</sup> are selected from the group consisting of hydrogen (H) atoms, heteroatom-containing functional groups, alkyl groups, heteroatom-containing alkyl groups, cyclic groups, heteroatom-containing cyclic groups, aromatic groups, heteroatom-containing aromatic groups, and combinations thereof. In addition, the system can comprise at least one polishing additive selected from the group consisting of a carboxylic acid (preferably, a di-, tri-, or poly-carboxylic acid), a phosphate (preferably, a

pyrophosphate, a tri-phosphate, or a condensed phosphate), an acid thereof, and a phosphonic acid (preferably, a di-, tri-, or poly-phosphonic acid) and at least one stopping compound comprising an aminopropyl group and/or at least one stopping compound having a molecular weight (MW) of about 80 or more (e.g., a MW of about 100 or more, a MW of about 250 or more). Furthermore, the system can comprise a peroxide, aminotri(methylenephosphonic acid), and 1,4-bis(3-aminopropyl)piperazine, and optionally, at least one passivation film forming agent comprising one or more 5-6 member heterocyclic nitrogen-containing rings. The system also can comprise a peroxide, tartaric acid, and a polyethylenimine, and, optionally, at least one passivation film forming agent comprising one or more 5-6 member heterocyclic nitrogen-containing rings.

*Replace the paragraph beginning at page 11, line 22, with:*

The system of the present invention further can comprise a source of ammonia (e.g., ammonia or an ammonium salt). Ammonia and/or ammonium salts enhance the removal rate and/or removal selectivity (e.g., Cu:Ta removal selectivity) of the system, by interacting with one or more components of the system (e.g., the polishing additive). Preferably, the system of the present invention comprises ammonia and/or ammonium salts and one or more polishing additives. Preferably, the system comprises a source of ammonia and at least one polishing additive selected from the group consisting of a carboxylic acid (preferably, a di-, tri-, or poly-carboxylic acid), a phosphate (preferably, a pyrophosphate, a tri-phosphate, or a condensed phosphate), an acid thereof, and a phosphonic acid (preferably, a di-, tri-, or poly-phosphonic acid). For example, the system can comprise aminotri(methylenephosphonic acid) and a source of ammonia (e.g., ammonia and/or an ammonium salt).

*Replace the paragraph beginning at page 11, line 34, with:*

Suitable polymeric compounds include, for example, any suitable polymeric compound that reduces the polishing rate of at least one layer associated with the substrate. Preferably, the system comprises at least one polymeric compound comprising a polyvinylalcohol, a polyethylene oxide, a polypropylene oxide, a sulfonic acid polymer, a sulfonate polymer, or a mixture thereof.

*Replace the paragraph beginning at page 16, line 14, with:*

These results demonstrate the significance a polishing additive comprising the XY-NCR<sub>2</sub>CR<sub>2</sub>N-X'Y' moiety in the context of the present inventive system, as well as the significance of the ratio of primary:secondary:tertiary amino groups in the

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XY-NCR<sub>2</sub>CR<sub>2</sub>N-X'Y' moiety of the polishing additive, on the polishing rate achievable by the present inventive system and method.

*Replace the paragraph beginning at page 16, line 24, with:*

Copper wafers and tantalum wafers were polished separately with sixteen different polishing systems (designated Systems 3A-3P) with 3 wt.% alumina (specifically, Cabot's Semi-Sperse® W-A355 product), 2.5 wt.% oxidizing agent (specifically, H<sub>2</sub>O<sub>2</sub>), and either 0.5 wt.% or 1 wt.% of a polishing additive (specifically, 1-diphosphonic acid (i.e., Dequest® 2010 product), diethylenetriaminepenta(methylenephosphonic acid) (i.e., Dequest® 2060 product), N-phosphonomethyliminodiacetic acid, Lupasol® FG, 1,3-diamino-2-propanol, 2-imino-4-thiobiuret, iminodiacetic acid, dimethylglyoxime, dipyridylamine, iminodiacetonitrile, guanidine nitrate, pyrazinecarbonitrile, thioglycolic(mercaptoacetic)acid, thiadipropanionic acid, 1 wt.% of an ethoxylated high molecular weight polyethylenimine (i.e., Lupasol® SC-61B), or a modified high molecular weight ethylenimine polymer (i.e., Lupasol® SKA)), wherein each of the systems had a pH of 5 (Systems 3C, 3F, 3H, 3I, 3K, 3L, 3O, and 3P) or a pH of 7.7 (Systems 3A, 3B, 3D, 3F, 3G, 3J, 3M, and 3N).

*Replace the Table 3 beginning at page 17, line 5, with:*

Following use of the systems, the removal rate (RR) of copper and tantalum by each system was determined, as well as the relative removal of copper to tantalum ("Cu:Ta"). The resulting data are set forth in Table 3.

Table 3:

System	Polishing Additive	Cu RR [Å/min]	Ta RR [Å/min]	Cu:Ta
Control	None	87	198	1:2
3A	1 wt.% Dequest® 2010	4777	406	12:1
3B	1 wt.% Dequest® 2060	7624	279	27:1
3C	1 wt.% N-phosphonomethyl-iminodiacetic acid	4333	314	14:1
3D	1 wt.% Lupasol® FG	733	13	56:1
3E	1 wt.% 1,3-diamino-2-propanol	2668	50	53:1
3F	1 wt.% 2-imino-4-thiobiuret	1216	95	13:1
3G	1 wt.% iminodiacetic acid	7738	533	15:1
3H	0.5 wt.% dimethylglyoxime	1153	273	4:1

3I	0.5 wt.% dipyridylamine	3022	264	11:1
3J	1 wt.% iminodiacetonitrile	243	446	1:1:8
3K	0.5 wt.% guanidine nitrate	281	289	1:1
3L	0.5 wt.% pyrazinecarbonitrile	246	323	1:1.3
3M	1 wt.% thioglycolic(mercaptoacetic) acid	552	263	2:1
3N	1 wt.% thiodipropanionic acid	652	250	2.6:1
3O	1 wt.% Lupasol® SC-61B	682	14	49:1
3P	0.5 wt.% Lupasol® SKA	480	15	32:1

*Replace the paragraph beginning at page 19, line 18, with:*

Copper wafers, tantalum wafers, and silicon dioxide ( $\text{SiO}_2$ ) wafers were polished separately with eight different polishing systems (designated Systems 5A-5G) with 3 wt.% alumina (specifically, Cabot's Semi-Sperse® W-A355 product), 2.5 wt.% oxidizing agent (specifically,  $\text{H}_2\text{O}_2$ ), varying concentrations of a polishing additive (specifically, 1.25 wt.% tartaric acid, 0.5 wt.% 1-diphosphonic acid (i.e., Dequest® 2010 product), 0.75 wt.% aminotri(methylenephosphonic acid) (i.e., Dequest® 2000 product), 0.8 wt.% Dequest® 2010 product, or 2.5 wt.% Dequest® 2000 product), and varying concentrations of a stopping compound (specifically, 0.25 wt.% Lupasol® SKA, which contains 25% of an ethylenimine polymer (i.e., 0.06 wt.% polyethylenimine), 0.1 wt.% dicyanoimidazole, 0.5 wt.% Lupasol SKA (i.e., 0.12 wt.% polyethylenimine), 0.5 wt.% polyacrylamide, or 0.5 wt.% 1,4-bis(3-aminopropyl)piperazine, or 0.5 wt.% Varisoft® 300, which contains cetyl trimethylammonium chloride, wherein each of the systems had a pH of 5 (System 5E) or a pH of 7.7 (Systems 5A-5D, 5F-5G). Moreover, System 5C contained 0.005 wt.% surfactant (specifically, Triton DF-16).

*Replace the paragraph beginning at page 24, line 5, with:*

Copper wafers, tantalum wafers, and silicon dioxide ( $\text{SiO}_2$ ) wafers were polished separately with fourteen different polishing compositions with 3 wt.% alumina (specifically, Cabot's Semi-Sperse® W-A355 product), 2.5 wt.% oxidizing agent (specifically,  $\text{H}_2\text{O}_2$ ), 1 wt.% polishing additive (specifically, ammonium oxalate ( $(\text{NH}_4)_2\text{C}_2\text{O}_4$ )), and varying concentrations of a stopping compound (specifically, 0.2 wt.% isophoronediamine, 0.2 wt.% hexamethylenediamine, 0.2 wt.% N-cyclohexyl-1,3-propanediamine, 0.2 wt.% N-(3-aminopropyl)-1,3-propanediamine, 0.2 wt.% tetraethylenepentamine, 0.2 wt.% N,N,N',N'-tetramethyl-1,4-butanediamine, 0.5 wt.% propylamine, 0.2 wt.% 2-(2-aminoethoxy)ethanol, 2.0 wt.% 1,3-diamino-2-propanol, 1.0 wt.% thiomicamine, 3.0

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wt.% 2-amino-1-butanol, 0.2 wt.% 4,7,10-trioxa-1,13-tridecanediamine, 0.2 wt.% lysine, 0.2 wt.% poly[bis(2-chloroether)-*alt*-1,3-bis(3-dimethylamino)propyl], wherein each of the systems had a pH of 7.6. For comparison purposes, the test wafers also were polished with a control system ("control") with 3 wt.% alumina (specifically, Cabot's Semi-Sperse® W-A355 product), 2.5 wt.% oxidizing agent (specifically, H<sub>2</sub>O<sub>2</sub>), and 1 wt.% polishing additive (specifically, ammonium oxalate (NH<sub>4</sub>)<sub>2</sub>C<sub>2</sub>O<sub>4</sub>), wherein the control system had a pH of 7.6. Following use of the polishing compositions, the relative tantalum (Ta) removal rate and the relative silicon dioxide (SiO<sub>2</sub>) removal rate of each system were determined in comparison with the removal rates of the control system, with the resulting data set forth in Table 7.

Table 7:

System	Stopping Compound	Relative Removal Rate Ta	Relative Removal Rate SiO <sub>2</sub>
Control	none	1	1
7A	0.2 wt.% isophoronediamine	0.17	-
7B	0.2 wt.% hexamethylenediamine	0.24	0.27
7C	0.2 wt.% N-cyclohexyl-1,3-propanediamine)	0.12	0.11
7D	0.2 wt.% N-(3-aminopropyl)-1,3-propanediamine	0.17	0.03
7E	0.2 wt.% tetraethylenepentamine	0.21	0.13
7F	0.2 wt.% N,N,N',N'-tetramethyl-1,4-butanediamine	-	0.37
7G	0.5 wt.% propylamine	0.17	-
7H	0.2 wt.% 2-(2-aminoethoxy)ethanol	0.71	-
7I	3.0 wt.% 2-amino-1-butanol	0.04	0.21
7J	0.2 wt.% 4,7,10-trioxa-1,13-tridecanediamine	0.28	0.22
7K	0.2 wt.% lysine	0.35	1.1
7L	0.2 wt.% poly[bis(2-chloroether)- <i>alt</i> -1,3-bis(3-dimethylamino)propyl]	-	0.33